3. Repairs to shells damaged mechanically, by filing the aperture, grinding holes in the body and upper whorls, and by cracking in a vise are described.

LITERATURE CITED

Bonar, L.
1936. An unusual ascomycete in the shells of marine animals. Univ. Calif. Publ. Bot. 19: 187 - 194

Fretter, Vera, & Alastair Graham
1962. British prosobranch molluscs; their functional anatomy and ecology. London, Ray Soc.; xvi + 755 pp.; 317 figs.

Johnson, T. W., Jr. & W. A. Anderson
1962. A fungus in *Anomia simplex* shell. Journ. Elisha Mitchell Sci. Soc. **78**: 43 - 47

McGee, Patricia
1964. A new pigment from *Tegula funebralis* (Mollusca: Gastropoda). The Veliger 6; Supplement: 25 - 27; 1 text fig.

The Dispersal of Young of the Commensal Gastropod *Crepidula adunca* from its Host, *Tegula funebralis*

BY

DEBORAH A. PUTNAM

Hopkins Marine Station of Stanford University,
Pacific Grove, California

(4 Text figures)

INTRODUCTION

Crepidula adunca Sowerby, 1825 is a protandric marine prosobranch commonly found on the shells of *Tegula funebralis* (A. Adams, 1854), both when the latter is occupied by the snail and when it is occupied by *Pagurus* spp. Moritz (1938) gives the range of *C. adunca* as being similar to that of *T. funebralis*: from Vancouver, British Columbia, to the tip of Lower California. Conklin (1897) has followed the cell lineage of *C. fornicata* and *C. plana,* and Moritz (1938, 1939) has treated the anatomy and organogenesis of *C. adunca.*

Crepidula adunca undergoes a very direct development from large, yolky eggs which are brooded by the female. The hatching young crawl out of the egg cases as juveniles which are similar to adults. At hatching there may be from 150 to 200 young released. Although no pelagic stage is present, the adult population of *C. adunca* is quite well dispersed over the *Tegula funebralis* population near the Hopkins Marine Station, Pacific Grove, California. The number of adult *C. adunca* per *T. funebralis* shell is relatively low (eight was the maximum number seen) as compared to the large number of young per brood. Clearly, the young become dispersed to new hosts without benefit of a pelagic stage. How this is accomplished is the subject of the present investigation.

HATCHING

Crepidula adunca breeds the year round (Moritz, 1938). The animals used were gathered from Mussel Point, Pacific Grove, California. *Tegula funebralis* with the brooding *Crepidula* females were kept in glass finger bowls at 12 to 18° C. Young when hatched were kept similarly. All young used in all experiments were hatched without human assistance, both to avoid harming the young through attempts to liberate them artificially, and to establish their age, as the period of development to hatching is not known.

In the four cases where hatching was observed, young *Crepidula adunca* were released between 8:30 and 10:30 a. m. The egg cases are attached by individual stalks to one spot on the *Tegula funebralis* shell. immediately ventral and posterior to the head and anterior to the foot of the female *C. adunca.* Normally, the female's shell is lifted no more than 0.5 mm above the substrate, only enough to allow water to flow through the mantle cavity for filter-feeding and respiration. During hatching, however, the female intermittently lifts her shell 1 to 3 mm above the substrate, for periods which varied from 3.5 seconds to about 4 minutes. Then with a forward and downward motion of her head over the egg cases, the female pushes out those of her young which are loose

and in the path of her head. Other hatched young may crawl out. The young usually escape from the anterior region of the mother's shell, which is typically oriented on the host as shown in Figure 1.

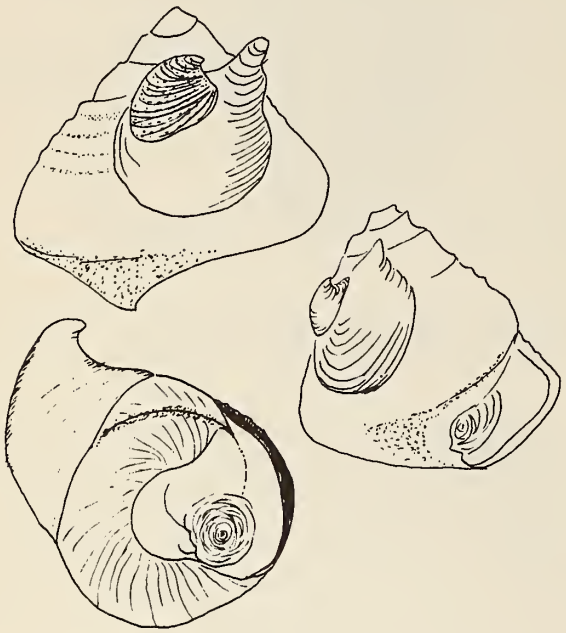

Figure 1: Orientation of *Crepidula adunca* on *Tegula funebralis.*

The egg cases themselves may be expelled immediately at the end of hatching, which takes approximately one half hour, or after several days. Not all egg capsules under a given female are necessarily at the same stage of development or hatch at the same time.

THE NEWLY HATCHED YOUNG

The average newly hatched *Crepidula adunca,* based on the measurement of six broods, is 1.19 mm long and 0.91 mm wide. The spat when hatched are very motile. They show no tendency to avoid either the mother or the host; however, many of the spat fall off the *Tegula funebralis* immediately. The number of spat leaving the host is increased by any current present; mucus still covers the spat, and they do not adhere well to any surface. Less than ten percent of a brood remain on the parental host even in still water, where the only motion is that resulting from the creeping of *T. funebralis.* The few young remaining on the host become quiescent sooner and remain so longer than those which fall off.

The young which fall off sink to the bottom. Mucus adhering to the young affects the rate of sinking, which ranges from about 1.1 to 2.6 cm/sec (average 1.4 cm/sec). Once off the host, the young are quite active. Their movement seems random; they are neither attracted to nor repelled by each other. There is a net movement upward and towards a light, if this is not too intense. These actions may even lead the spat to crawl out of the water, where they dessicate and die within 15 to 20 minutes on a sunny day. It is perhaps an advantage, therefore, for the newly hatched spat to be washed off the host *Tegula funebralis,* which is normally exposed during the tidal cycle. Sunlight alone has no effect on the newly hatched *Crepidula adunca* when they are immersed.

The spat are very active even in still water, and their random movements tend to disperse them. Simple dispersal experiments were carried out in eight finger bowls with newly hatched young. Ten juveniles were placed in the center of each bowl and their positions marked on a grid at five minute intervals. Average motility, based on these runs, is plotted in Figure 2. Maximum rate of locomotion measured over a short distance was about 0.2 mm/sec.

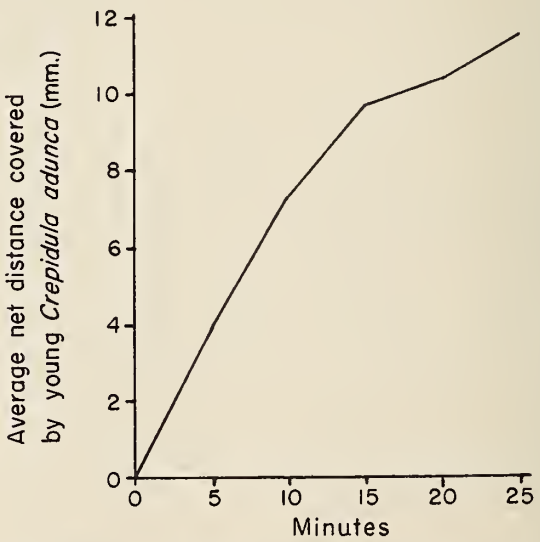

Figure 2: Average net distance covered by young *Crepidula adunca.*

A weak current of water stimulates the spat, which tend to orient upstream and move into the current. In stronger currents the spat clamp down and remain immobile unless torn loose by the current. The ability of spat to cling in currents of varying rates of flow is shown in Figure 3.

RESPONSES OF JUVENILE *Crepidula adunca* TOWARD *Tegula funebralis* AND ADULT *Crepidula adunca*

Preliminary experiments indicated that adult female *Crepidula adunca,* removed from their hosts, usually attempted to climb back on, and that adult males are attracted by *Tegula funebralis,* but even more strongly by female *C. adunca.* In contrast, the newly hatched spat do not appear to be strongly attracted either to *T. funebralis* or to older *C. adunca,* male or female. The reactions of juveniles to parents and host were tested as follows.

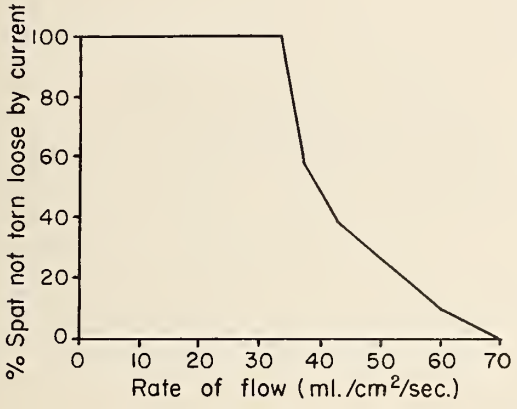

Figure 3: Ability of juvenile *Crepidula adunca* to cling to a glass surface in a current. Up to 34 ml/cm²/sec flow, random movement continued, with a slight net orientation into the current. Above this, the spat clamped down tightly.

Ten newly hatched young were placed in the center of each of four finger bowls. To each of three bowls was added, near the edge, one of the following: 2 living male *C. adunca,* an empty *T. funebralis* shell, or a living female *C. adunca.* The fourth bowl served as a control. The positions of the young free in the bowls or on the various proffered substrates were recorded daily for a period of twelve days (Figure 4).

There is no evidence that the spat are attracted to *Tegula funebralis* or *Crepidula adunca.* Instead, the young appear to move at random. However, when they come in contact with any one of these shells, they crawl upon it, and their motility thereafter is greatly decreased. The presence of the living animal is not a factor; as many settle on an empty *C. adunca* shell as on one that is occupied. In supplementary experiments fewer settled on

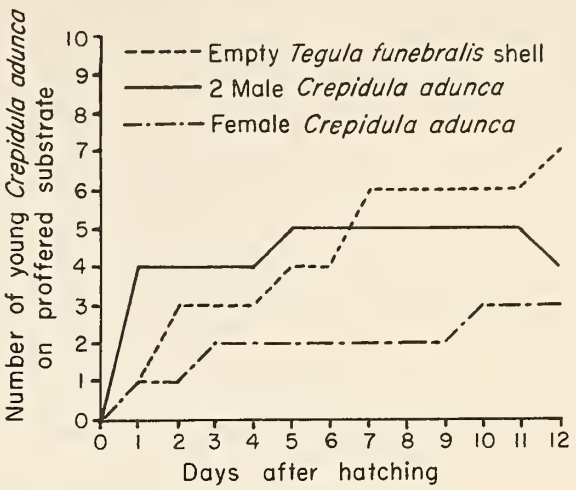

Figure 4: Settlement of spat on various substrates.

an occupied *T. funebralis* shell than an empty one, presumably due to the comparatively rapid motion of the larger snail.

The attraction to *Tegula funebralis* must increase as spat grow older, since the adult population lives on this host and shows a clear positive response to it. However, this investigator found no *Crepidula adunca* smaller than 3.8 mm in length, 2.8 mm in width and 2.0 mm in height, on a *T. funebralis* in the field. Searches for spat or young adults on rocks, in shells and gravel, and on algae were unsuccessful.

Adult *Crepidula adunca* are filter-feeders. However, the ciliated food groove does not appear until after hatching, nor does the food pouch develop until after the young adult stage (Moritz, 1939). Scraping motions with the radula in the young have been observed, which strongly suggests that the spat may obtain microscopic food by this means. The young might not be strongly attracted to *Tegula funebralis* or to another, older *C. adunca* until their filter-feeding apparatus has developed.

SUMMARY

Crepidula adunca is a protandric marine prosobranch commonly found on the shells of *Tegula funebralis.* Female *C. adunca* are oriented in a consistent manner on the whorls of the *T. funebralis* shell. There is no free-swimming larval stage; the brooded young crawl or are pushed out from under the mother as juveniles similar in form to the adults. The newly hatched spat are very motile; the great majority drop off the host and sink. Weak water currents stimulate the spat; there is net orientation into current, against gravity, and toward moderate light.

Spat are only weakly attracted to either *T. funebralis* or older *C. adunca*; this attraction is clearly present in older individuals.

LITERATURE CITED

Conklin, E. G.

1897. The embryology of *Crepidula*. Journ. Morph.13: 1 - 226; plts. 1 - 9; 13 text figs.

Moritz, Charles E.

1938. The anatomy of the gasteropod *Crepidula adunca* Sowerby. Univ. Calif. Publ. Zool. 43: 83 - 92; 6 text figs.

1939. Organogenesis in the gasteropod *Crepidula adunca* Sowerby. Univ. Calif. Publ. Zool. 43: 217 - 248; 22 text figs.

Studies on the Commensal Limpet *Acmaea asmi* in Relation to its Host, *Tegula funebralis*

BY

ARTHUR B. EIKENBERRY JR.

AND

DIANE E. WICKIZER

Hopkins Marine Station of Stanford University,
Pacific Grove, California

(11 Text figures; 2 Tables)

Acmaea asmi (Middendorff, 1849) is a stenotopic limpet which inhabits the rocky intertidal, and lives almost exclusively on *Tegula funebralis* (A. Adams, 1854). By studying distribution in relationship to horizontal and vertical position in the intertidal and by considering distribution in relationship to food and substrate preferences, we hoped to establish a clearer understanding of the adult commensal relationship between *A. asmi* and *T. funebralis*. The following work is a continuation and refinement of studies carried out by Frederick H. Test in 1945, and Ruth Radford in 1959.

DISTRIBUTION

During April and May, 1963, distribution of *Acmaea asmi* was studied along Mussel Point on Monterey Bay, California. Every *A. asmi* noted along five transects by W. Wara & B. Wright (1964, see Figures 1 - 5) was collected with its host and both organisms were measured. Notation of horizontal and vertical position was made.

Since the five transects varied both in length and in slope, horizontal distribution in terms of absolute distance from shore is not particularly significant. However, in all five transects populations were concentrated in the middle areas, the regions affected neither by shore line wave action nor the wave battering of the outer intertidal. 6 186

Furthermore, observations at high tide (Wara & Wright, 1964) revealed a qualitative difference in wave action between the transects and showed that the number of *Acmaea asmi* was generally inversely proportional to the wave battering received by the area. Qualitatively, Area B had very heavy wave action and no *A. asmi* were found; Area A received a heavy battering and the density of *A. asmi* was low. As the wave action decreased from